MINIATURE NEUTRON-ALPHA ACTIVATION SPECTROMETER.  E. Rhodes$^1$ and J. Goldsten$^2$, 1Johns Hopkins University Applied Physics Laboratory, 11100 Johns Hopkins Road, Laurel, MD 20723-6099, ed.rhodes@jhuapl.edu, 2Johns Hopkins University Applied Physics Laboratory, john.goldsten@jhuapl.edu.

Introduction: We are developing a miniature neutron-alpha activation spectrometer for in-situ analysis of samples including rocks, fines, ices, and drill cores, suitable for a lander or Rover platform, that would meet the severe mass, power, and environmental constraints of missions to the outer planets. In the neutron-activation mode, a gamma-ray spectrometer will first perform a penetrating scan of soil, ice, and loose material underfoot (depths to 10 cm or more) to identify appropriate samples. Chosen samples will be analyzed in bulk in neutron-activation mode, and then the sample surfaces will be analyzed in alpha-activation mode using Rutherford backscatter and x-ray spectrometers. The instrument will provide sample composition over a wide range of elements, including rock-forming elements (such as Na, Mg, Si, Fe, and Ca), rare earths (Sm and Eu for example), radioactive elements (K, Th, and U), and light elements present in water, ices, and biological materials (mainly H, C, O, and N). The instrument is expected to have a mass of about 1 kg and to require less than 1 W power.

Focus Area: By selection of construction materials and detectors and design modifications, this instrument can be adapted to a number of mission requirements and space environments, including surface exploration of comets and moons, such as Titan and Triton. Data from this instrument can provide some inferences into prebiotic conditions, petrology, planetary differentiation, igneous evolution, and weathering history. But also, because of its penetrating scanning capability over the body’s surface in neutron activation mode, this instrument can select promising samples as the front end of a landed instrument suite including possibly a core driller and specialized mass and infrared spectrometers, that together can provide more definitive information and support the decision to cache appropriate samples for return to earth. Otherwise precious resources can be wasted collecting and measuring uninteresting samples from the vast array of candidates available on the body’s surface.

Key Technologies: Novel to our approach are two enabling technologies, a switchable radioactive neutron source (SRNS) and a small high-resolution gamma-ray detector (SHGD). The SRNS is based on the separation of alpha-emitting radioisotope material and light-element material such as Be, B, or Li, that have a large alpha cross section for generating neutrons. When the alpha emitter material is placed in close proximity to the light element material, the neutron source is switched on. When the materials are separated, the neutron source is switched off, preventing unwanted activation and radiation damage to space craft and instrument components when measurements are not being made, without any massive shield. The only other available switchable neutron source is accelerator-based and requires power for bulky ancillary equipment not needed by the SRNS, such as an ultra-high voltage supply (which tends to be relatively unreliable). The SRNS yields a reasonably high neutron flux but is small and requires very little power.

The SHGD consists of a small high-purity Ge (HPGe) or Cd-Zn-Te (CZT) gamma detector inside a bismuth germinate anticoincidence cup, along with low-power digital signal processing electronics. HPGe provides the best energy resolution and efficiency and is the material of choice, but requires low temperature operation. In warm environments, CZT would be used. The cup provides suppression of cosmic rays and detector gamma scattering, along with an escape coincidence mode that further suppresses background at energies above 1 MeV. This detector will yield adequate energy resolution and efficiency for analysis of all gamma lines up to 3.5 MeV (above the C/O double-escape peak), which covers all elements of interest.

Development Base: The SRNS has been patented by one of the authors and it has been demonstrated that a stable SRNS can be made that acts as a strong neutron source [1] ($10^8 - 10^9$ n/s). The technologies for deployment of HPGe detectors in space are well known. CZT detectors are beginning to be considered for space missions and questions concerning radiation damage, operating temperature range, and other environmental concerns are not yet answered, but the necessary technologies will develop rapidly and APL has a collaboration with a primary CZT developer [2]. The authors have experience developing nuclear spectrometers, analyzing their spectra, and their deployment in space. APL has a long history of successful development and deployment of space craft, including suites of highly sophisticated state-of-the-art instrumentation and involving adaptations to a wide variety of mission requirements and space environments.